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Water-in-Oil-in-Water (W/O/W) Double Emulsion Morphology and Its Degradation on Instant Noodle Seasoning

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ABSTRACT

This experiment aims to the observed morphology, reduction of fineness and distribution particle deterioration of W/O/W double emulsion in instant noodle seasonings which is kept in 3 weeks with different storage temperature and NaCl level treatments. Emulsion structure has an important role to hamper salt release rate from internal to external phase. Structure breakdown shows system inability to maintain continuous salty taste perception during consumption because of the increasing salt release rate in storage period of instant noodle seasoning. Samples are treated with 3 variations of storage temperatures which are low (4 °C), room (25 °C), high temperature (40 °C) and 6 variations of NaCl level which are 0; 0,2; 0,4; 0,6; 0,8; 1%. Samples are categorized into 2 groups, double emulsions, and instant noodle seasonings. The double emulsion is made by 2 phases emulsification to get primary W/O emulsion and final W/O/W emulsion. This experiment showed that low and high-temperature storage affected emulsion and seasoning particle morphology, fineness and distribution throughout several instability phenomena.

Keywords: Double emulsion; morphology; seasoning

INTRODUCTION

The double emulsion is a complex system of emulsion within the emulsion. There are two types of the double emulsion, O/W/O (oil-in-water-in-oil) and W/O/W (water-in-oil-in-water) (Luo *et al.*, 2017). O/W/O emulsion is a double emulsion in which water is dispersed in oil and then the oil is dispersed back in the water, whereas W/O/W emulsion is the opposite of O/W/O emulsion. W/O/W double emulsion is more commonly used than O/W/O double emulsion because of its solubility properties (Yan *et al.*, 2013). The emulsion has been developed in various industries such as pharmacy, cosmetics, and food. The advantage of double emulsion over simple emulsion is its internal phase ability to bring hydrophilic active components. The entrapment of active components in the internal phase by means of the coating through the external oil and water phase slows down the release rate and degradation of active components up to a certain duration (Sapei, *et al.*, 2012). The existence of internal phase in W/O/W double emulsion can be used as one of the alternative methods to encapsulate NaCl and to reduce salt content in food products (Pawlik *et al.*, 2013).

The application of W/O/W double emulsion in food products has been growing steadily. Muschiolik & Dickinson, 2017 show previous researches on the application of double emulsion in liquid food products such as mayonnaise or low calorie cream (Matsumoto and Kohda, 1979), low fat salad dressing and spread margarine (Gaonkar, 1994), milk fat substitution in cheese (Lobato-Calleros *et al.* 2006) and dry food products such as film and powder coating. Research on W/O/W double emulsion application in instant noodle seasoning hasn't been performed in earlier studies, however, research on W/O/W double emulsion application in dressing performed by Taki *et al.* (2007) has produced a patent.

W/O/W double emulsion is potential to be applied in instant noodle seasoning. Instant noodle seasoning is one of the food products with a relatively high salt content commonly consumed by people. Nikkei Asian (2016) revealed that the seasoning in one cup of Nissin instant noodle contributes 2.3 grams of salt per serving. The number is quite high if compared to the salt consumption limit set by the WHO and by the Republic of Indonesia's Minister of Health Decision in 2014, which is 5g/capita/day. Double emulsion application in instant noodle seasoning aims at retaining the salty taste of the seasoning without lowering the amount of salt added. The salt release rate from the internal phase is delayed by the oil coating so that the salty taste can be constantly maintained immediately after consumption.

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The structure of double emulsion has an important role in maintaining salt to remain in the internal water phase during storage (Appelqvist, Golding, Vreeker, & Zuidam, 2007). Double emulsion structure degradation during storage shows that there is an increase of salt release rate from the internal water phase. The release of salt into the external water phase before consumption has caused the imperfect salt release mechanism. This is due to the fact that salt has already been in the external water phase so that the emulsion cannot continuously give the salty taste perception during consumption process. Emulsion morphology plays a role in showing the wholeness and form of each double emulsion constituent. Particle fineness and distribution contribute to showing the level of double emulsion particles' even distribution in the system. A system with an even spread of emulsion particle size or homogenous is called monodispersion, whereas the system with the varied spread of particle size heterogeneous is called polydispersion.

This research aims to observe morphological degradation, fineness reduction, and particle distribution of W/O/W double emulsion in instant noodle seasoning based on storage temperature differences and NaCl content during a 3-week storage.

RESEARCH METHOD

Ingredients

The ingredients used for making of double emulsion are aquademin obtained from Chemistry Research Center, Indonesian Institute of Science (Puslit) LIPI, Tangerang, Indonesia; gelatin (Brataco, Indonesia); NaCl (Merck, Germany); soy oil (Indofood, Indonesia); Span 80 lipophilic emulsifier (Merck, Germany); Tween 80 hydrophilic emulsifier (Merck, Germany), soy protein isolate (Cipta Kimia, 92%, Solo, Indonesia); and Arabic gum (Merck, Germany). The ingredients used for the making of seasoning are liquid sugar (Rose Brand, Indonesia); garlic powder (Jay's, Indonesia); onion powder (Jay's, Indonesia); maltodextrin (Dongxiao, China); dried parsley (Jay's, Indonesia); chicken flavor (Jay's, Indonesia); white pepper powder (Koepoe-Koepoe, Indonesia); and sweet soy sauce (Bango, Indonesia). The ingredient used for analysis is aquadestilata from Puslit LIPI, Tangerang, Indonesia.

Tools

The tools used for making double emulsion are Yellow Line DI 25 homogenizer (IKA, Germany); C-MAG HS 7 magnetic stirrer (IKA, Germany), magnetic stirrer (Thermo scientific, USA), HP-3000 magnetic stirrer (Lab companion, USA), SB24001 digital scale (Mettler Toledo, USA), ABJ-NM/ABS-N analytic scale (Kern, Germany), refrigerator (Bosch, Germany), XMT-152A oven (Autcomp, China), LS 100Q particle size analyzer (PSA) (Beckman Coulter, USA), CKX41 optical microscope (Olympus, Japan), video camera (Meiji Techno, Japan), IX73 optical microscope (Olympus, Japan), DP73 video camera (Olympus, Japan), *preparat* glass and *preparat* glass cover.

Research Stages

This research involves two treatments, namely NaCl and storage temperature. Na Cl content consists of six variations, namely 0% (T0) as control; 0.2% (T1); 0.4% (T2); 0.6% (T3); 0.8% (T4) and 1% (T5). Storage temperature consists of three variations, namely low temperature (4 ºC); room temperature (25 °C) and high temperature (40 °C).

Making W/O/W Double Emulsion

The double emulsion is made through 2 stages, namely primary emulsification by emulsifying internal water phase or A_1 (40%) to the oil phase or M (60%), followed by secondary emulsification, which is emulsifying emulsion A_1/M to external water (A_2). The W/O/W double emulsion composition can be seen in Table 1. The internal water phase is obtained through sodium chloride (NaCl) hydration in aquademin for 30 minutes, and then gelatin is added and stirred using magnetic stirrer for 25 minutes in a temperature of 65 °C. The oil phase is obtained by adding Span 80 lipophilic emulsifier into soy oil and then stirred using a magnetic stirrer for 25 minutes in a temperature of 65 °C. The internal water phase is emulsified into oil phase using Ultraturrax homogenizer at 15.000 rpm speed for 10 minutes to get A_1/O. External water phase (80%) is achieved by mixing soy protein isolate, Arabic gum, and Tween 80 hydrophilic emulsifier into aquademin and stirred using a magnetic stirrer for 30 minutes at 25 °C temperature. A_1/O (20%) is re-emulsified to external water phase using Ultraturrax homogenizer at 15,000 rpm speed for 3 minutes until W/O/W is formed. The double emulsion is stored at three different storage temperatures for 3 weeks.

Table 1. W/O/W Double Emulsion Formula

Phase	Ingredient	NaCl composition in double emulsion (% net weight)					
		T0	T1	T2	T3	T4	T5
A_1	Aquademin	6.00	5.80	5.60	5.40	5.20	5.00
	Gelatin	2.00	2.00	2.00	2.00	2.00	2.00
	NaCl	0.00	0.20	0.40	0.60	0.80	1.00
M	Soy Oil	11.80	11.80	11.80	11.80	11.80	11.80
	Span 80	0.20	0.20	0.20	0.20	0.20	0.20
A_2	Aquademin	71.20	71.20	71.20	71.20	71.20	71.20
	Tween 80	0.80	0.80	0.80	0.80	0.80	0.80
	Arabic Gum	2.00	2.00	2.00	2.00	2.00	2.00
	Soy protein isolate	6.00	6.00	6.00	6.00	6.00	6.00

Making Instant Noodle Seasoning

Instant noodle seasoning is made by mixing W/O/W double emulsion with basic seasonings such as liquid sugar, garlic powder, onion powder, maltodextrin, dried parsley, chicken flavor, white pepper powder and sweet soy sauce. The composition of instant noodle seasoning can be seen in Table 2. Double emulsion (50%) is mixed with basic seasoning (50%) and then stirred using a magnetic stirrer for 60 minutes to get a homogenous mixture. The seasoning is stored in three different storage temperatures for 3 weeks.

Table 2. Instant noodle seasoning formula

Ingredients	NaCl composition in instant noodle seasoning (% nw)					
	T0	T1	T2	T3	T4	T5
Liquid sugar	10.00	10.00	10.00	10.00	10.00	10.00
Double emulsion	50.00	50.00	50.00	50.00	50.00	50.00
Garlic powder	6.00	6.00	6.00	6.00	6.00	6.00
Onion powder	5.00	5.00	5.00	5.00	5.00	5.00
Maltodextrin	6.00	6.00	6.00	6.00	6.00	6.00
Dried parsley	1.00	1.00	1.00	1.00	1.00	1.00
Chicken flavor	10.00	10.00	10.00	10.00	10.00	10.00
White pepper powder	2.00	2.00	2.00	2.00	2.00	2.00
Sweet soy sauce	10.00	10.00	10.00	10.00	10.00	10.00

Morphological Observation of Emulsion and Seasoning

Morphological observation of emulsion and seasoning is performed using a 4x magnification optical microscope which is connected to the computer. Emulsion and seasoning are dropped on the glass slide, and secured with a slide cover, and then observed upside-down. Morphological observation is performed before storage and in the second week of storage.

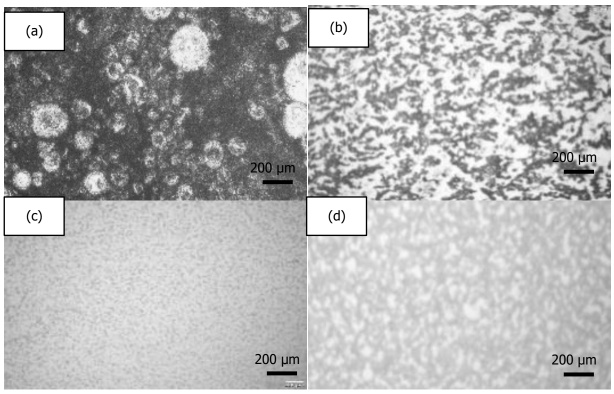
Emulsion and Seasoning Fineness and Particle Distribution

Fineness and particle distribution are tested using a particle size analyzer (PSA) which is connected to the computer. The solvent used in emulsion and seasoning fineness and particle distribution analysis is aquades. Aquades is dropped into the sample hole located on top of the PSA until it fills up the whole part, and then the emulsion and seasoning sample is dropped until the computer indicates an obscuration between 9-11%. The analysis is performed until output data is obtained. Particle fineness is interpreted based on D_{90} and D_{10} values. Particle distribution is interpreted based on D_{90} value. Fineness and particle distribution test are performed every week during the three weeks of storage.

RESULTS AND DISCUSSION

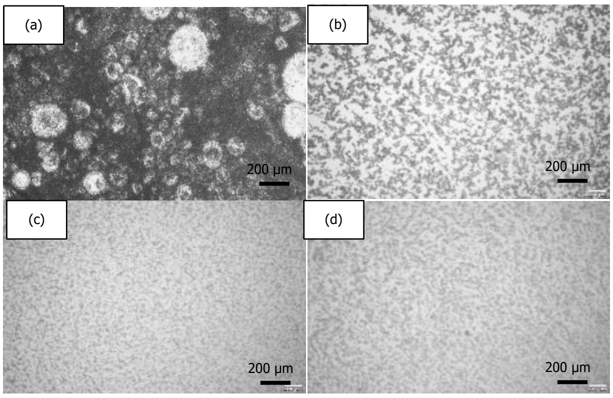
W/O/W Double Emulsion Morphology

W/O/W double emulsion morphology before and after storage is shown in Figures 1-4. Results of double emulsion morphology before storage show a similar tendency of a relatively large particle size with a single droplet structure, whereas double emulsion from the low-temperature and high temperature 2 week-storage show smaller droplet size and a droplet structure that sticks to one another. The morphology of W/O/W double emulsion from room temperature shows a different appearance from the other two at different storage temperatures. In this storage temperature, the droplets show a very small size with a single droplet structure. The morphological change indicates the phenomenon of emulsion instability such as diffusion, coalescence, and flocculation. Coalescence and flocculation occur on double emulsion at low temperature and high-temperature storage. Flocculation causes droplets to move closer and to stick to one another without involving any droplet core fusion, whereas coalescence is the clumping of emulsion droplets which reaches droplet core fusion. Dorst *et al*. (2004) stated that flocculation occurs in an emulsion system due to the weak force of repulsion among droplets, while the electrostatic force of attraction and van der Waals get stronger at the droplet surface. Aurora (2009) stated that coalescence in an emulsion system occurs through several stages, namely the meeting of droplet surfaces, formulation of thin film and damage of film which cause the two droplet cores to merge. Tadros (2013) stated that a coalescence is an event of the thinning and damage of inter-droplet film coating which causes fusion between two or more neighboring droplets. Droplet fusion causes the formation of one bigger droplet. The attachment of one droplet to another without involving a fusion causes an increase in droplet size with an uneven form. Morphological change occurs in room temperature storage double emulsion. Droplets experience changes in size, they become very small due to diffusion from the internal phase to external phase.

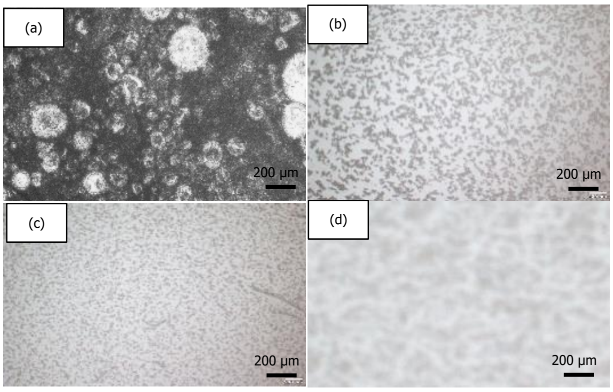


Remarks : (a) T0; (b) T1; (c) T3 and (d) T5

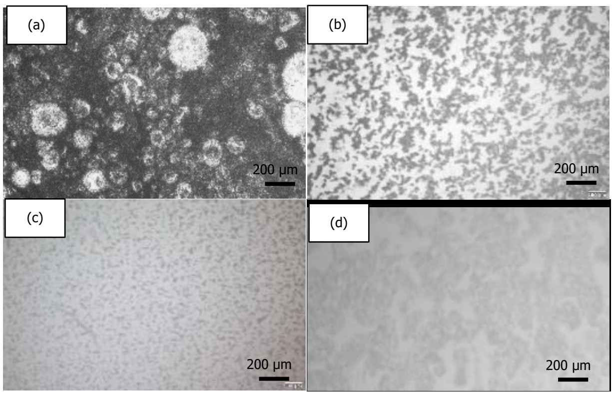
Figure 1. W/O/W double emulsion morphology T0



Remarks : (a) T0; (b) T1; (c) T3 and (d) T5
Figure 2. W/O/W double emulsion morphology T1



Remarks : (a) T0; (b) T1; (c) T3 and (d) T5
Figure 3. W/O/W double emulsion morphology T3



Remarks : (a) T0; (b) T1; (c) T3 and (d) T5
Figure 4. W/O/W double emulsion morphology T5

Overall, the difference in NaCl content doesn't show W/O/W double emulsion morphology differences. The difference in storage temperature shows different morphological tendencies. High storage temperature emulsion's morphological change is influenced by the changes of hydrophilic emulsifier characteristics. Komaiko and Mcclements (2016) stated that non-ionic emulsifiers like Tween have heat vulnerability characteristics. Heating process causes non-ionic emulsifier's main cluster to dehydrate and to become non-polar. Rousseau (2000) stated that on several conditions, emulsion at low-temperature storage has higher stability due to viscosity increase effect along with the temperature decrease. However, low-temperature storage also enables nucleation and crystallization which potentially destabilize the emulsion system. Fat crystallization in oil-in-water emulsion type causes destabilization through partial coalescence mechanisms.

W/O/W Double Emulsion Particle Fineness

Results of W/O/W double emulsion particle fineness test in Table 3 show that the higher the NaCl content, the lower the particle fineness. Provder (1987) stated that emulsion particle fineness is determined based on radius, area, and boundary of emulsion droplet. Merkus (2009) divided particle fineness parameter into six groups based on D90 values, namely < 0.1 μm (nano-particle); 0.1-1 μm (very fine); 1-10 (fine); 10-1000 μm (sufficiently fine); 1-10 mm (coarse) and >10 mm (very coarse). Particle fineness decreases in NaCl content of over 0.4% for low temperature and room temperature, whereas 0.2% applies for high temperature. This shows that NaCl content of less than 0.4% for low temperature and room temperature, and 0.2% for high temperature, is the effective content to retain particle fineness during the storage process.

The extremely high NaCl content can cause an imbalance in osmotic pressure between internal and external water phases. Diffusion process causes reduction of radius, area, and the boundary of droplets in the internal water phase, and the other way around in the external water phase. This is consistent with McClements' (2016) opinion which stated that the high concentration of solubles in internal water phase which causes the swelling of droplets is due to water diffusion from the external water phase. On the contrary, the high concentration of solubles in the external water phase causes a reduction of droplet size in the internal water phase due to diffusion from the internal water phase towards the external water phase.

W/O/W Double Emulsion Particle Distribution

W/O/W double emulsion with 0-1% NaCl content in 0-day storage overall shows a wide particle distribution. W/O/W double emulsion particle distribution is shown in Table 4. Low temperature and room temperature double emulsion with a 2-week storage duration also show a wide distribution classification. This is in line with the opinion of Balcaen *et al.* (2016), which stated that the double emulsion has a larger particle size and wider particle distribution than conventional emulsion. Double emulsion involves two steps of emulsification, namely primary emulsification to produce W/O emulsion using high shear stress, and secondary emulsion to produce W/O/W emulsion using low shear stress. The use of low shear stress in secondary emulsification aims at preventing damage to the internal water structure which causes the escape of the functional component being encapsulated. However, it brings an influence on the size and distribution of double emulsion particles.

Table 3. W/O/W double emulsion particle fineness

Treatment	Storage length (week)	Low temperature		Room temperature		High temperature	
		D_{90}	Particle fineness	D_{90}	Particle fineness	D_{90}	Particle fineness
T0	0	5.78	Very fine	5.78	Very fine	5.78	Very fine
	1	7.06	Very fine	6.54	Very fine	5.49	Very fine
	2	6.29	Very fine	6.32	Very fine	5.29	Very fine
	3	6.84	Very fine	7.26	Very fine	5.44	Very fine
T1	0	3.90	Very fine	3.90	Very fine	3.90	Very fine
	1	6.24	Very fine	4.93	Very fine	5.01	Very fine
	2	5.29	Very fine	4.84	Very fine	3.66	Very fine
	3	5.42	Very fine	5.42	Very fine	5.02	Very fine
T2	0	4.22	Very fine	4.22	Very fine	4.22	Very fine
	1	4.11	Very fine	4.41	Very fine	4.94	Fine
	2	4.25	Very fine	4.64	Very fine	5.71	Very fine
	3	5.16	Very fine	3.20	Very fine	5.18	Very fine
T3	0	8.72	Very fine	8.72	Very fine	8.72	Very fine
	1	8.70	Very fine	10.92	Fine	9.72	Very fine
	2	8.52	Very fine	9.20	Very fine	7.95	Very fine
	3	9.58	Fine	11.01	Very fine	8.33	Fine
T4	0	4.42	Very fine	4.42	Very fine	4.42	Very fine
	1	3.69	Very fine	9.02	Very fine	5.46	Very fine
	2	3.72	Very fine	3.77	Very fine	4.24	Very fine
	3	4.07	Very fine	3.81	Very fine	3.39	Very fine
T5	0	8.86	Fine	8.86	Fine	8.86	Fine
	1	10.97	Fine	10.29	Fine	10.52	Fine
	2	9.95	Fine	7.89	Very fine	7.96	Very fine
	3	10.28	Fine	28.26	Fine	11.25	Fine

High-temperature storage double emulsion shows a uniformed classification before storage and gets wider along with storage duration. Particle distribution classification refers to Merkus' (2009) opinion which stated that particle distribution is grouped into 5 based on D_{90}/D_{10} ratio, in which very wide distribution is for > 10 ratio; wide distribution for 4-10 ratio; sufficiently narrow distribution for 1.5-4 ratio; narrow distribution for 1.05-1.5; and uniformed distribution for <1.02 ratio. Low temperature and room temperature storage double

Table 4. W/O/W double emulsion particle distribution

Treatment	Storage length (in the week)	Low temperature		Room temperature		High temperature	
		D_{90}/D_{10}	Particle distribution	D_{90}/D_{10}	Particle distribution	D_{90}/D_{10}	Particle distribution
T0	0	5.90	Wide	5.90	Wide	5.90	Wide
	1	7.10	Wide	6.78	Wide	8.82	Wide
	2	7.24	Wide	6.70	Wide	6.45	Wide
	3	7.30	Wide	7.55	Wide	5.75	Wide
T1	0	5.27	Wide	5.27	Wide	5.27	Wide
	1	7.33	Wide	6.21	Wide	7.14	Wide
	2	7428.37	Very Wide	6.61	Wide	5.89	Wide
	3	6.62	Wide	6.79	Wide	6.88	Wide
T2	0	6.13	Wide	6.13	Wide	6.13	Wide
	1	6.25	Wide	6.55	Wide	4.84	Wide
	2	6.71	Wide	6.41	Wide	8.85	Wide
	3	7.66	Wide	4.83	Wide	7.77	Wide
T3	0	9.76	Wide	9.76	Wide	9.76	Wide
	1	9.17	Wide	10.59	Very Wide	10.71	Very Wide
	2	9.73	Wide	10.26	Very Wide	8.86	Wide
	3	9.44	Wide	12.27	Very Wide	8.31	Wide
T4	0	6.96	Wide	6.96	Wide	6.96	Wide
	1	5.79	Wide	13.42	Very Wide	8.78	Wide
	2	6.30	Wide	6.19	Wide	7.24	Wide
	3	6.48	Wide	6.24	Wide	5.85	Wide
T5	0	8.82	Wide	8.82	Wide	8.82	Wide
	1	9.87	Wide	9.57	Wide	9.78	Wide
	2	9.91	Wide	7.90	Wide	9.16	Wide
	3	9.28	Wide	21.91	Very Wide	10.59	Very Wide

emulsion particle distribution experience an increase along with storage duration, whereas high-temperature storage particle size tends to decrease. Emulsion particle distribution increase shows that particle homogeneity decreases along with storage duration. On the contrary, the decrease in particle distribution shows that homogeneity increases along with storage duration. Particle distribution changes along the storage process are influenced by flocculation, coalescence, and diffusion phenomena which take place on a portion of the whole emulsion particle. This causes the particle size to no longer be uniform and the particle size to be wider.

Balcaen *et al.* (2016) stated that double emulsion, in general, has a rather large particle size with wide particle distribution due to secondary emulsification process limitation. Secondary emulsification process which involves a high stress would damage the double structure of the emulsion. Emulsion particle distribution is also influenced by emulsifier absorption in each particle. This is in line with the opinion of Serie and El-nokaly (1991) which stated that the distribution of protein, low molecule weight surfactant (fat and its derivatives), and high molecular weight surfactant (polysaccharide and hydrocolloid) is the main factor in maintaining the formation, stability, and texture of food emulsion.

An emulsifier that is not well absorbed by particle surface causes the particle to lose repulsion and attraction forces in similar proportion. Particles with differing hydrophilic and hydrophobic cluster contents cause tendencies towards either of the phases (water or oil). Particles which absorb more hydrophilic emulsifier will tend to repulse oil, and vice versa. The instability causes particles to experience flocculation and coalescence.

Overall, it can be concluded that storage temperature and NaCl content influence particle morphology, fineness, and distribution. Low temperature and high-temperature storage cause a reduction in emulsifier’s ability through crystallization and dehydration phenomena. Overly high NaCl content causes an imbalance of osmosis pressure between internal and external water phases. Room temperature storage with maximum 0.4% NaCl content is the treatment which gives better particle morphology appearance, fineness, and distribution than other treatments.

Seasoning Morphology

Results of instant noodle seasoning morphological test before and after storage are shown in Figures 5-8.

Seasoning morphology shows an appearance that is different from the double emulsion. The differing appearance between emulsion and seasoning is influenced by the addition of basic seasoning, either in liquid or solid form. Solid basic seasoning will be better if it goes through a sifting process, using a strainer with a certain specific mesh to obtain particles with uniformed size. Basic seasoning particles’ uniformed size added to the emulsion is aimed at reducing the bias factor of emulsion morphology test on the emulsion. However, this research has not involved the straining process of basic seasoning. This is because the solid seasoning used is of commercial type, therefore, it is assumed that the particle size is uniform.

Seasoning with various NaCl contents and storage temperatures tend to show similar morphology in each week. Low temperature and room temperature storage seasoning show droplet structure change without a core, whereas high-temperature storage seasoning shows droplets which experience external phase swelling. This is consistent with droplet instability scheme according to Mezzenga *et al.* (2004), which stated that the disappearance of droplet core phenomenon occurs because of water diffusion from internal phase to external phase, whereas the swelling phenomenon occurs because of oil droplet coalescence. This is supported by Dickinson's (2011) opinion which stated that the coalescence mechanism that happens in both phases causes the displacement of some or all dispersed components from the internal phase to the external phase. Appelqvist *et al.* (2007) stated that the release of electrolytes from the internal phase to the external phase can happen to the system which has a balanced osmosis through reverse osmosis mechanism, Morphological test using an optical microscope in this research is only limited on the 2 dimensional structure, therefore, further observation using a confocal microscope is needed to obtain three dimensional structure.

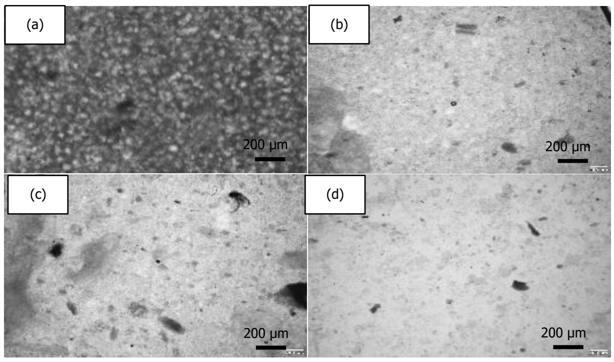


Figure 5. W/O/W double emulsion seasoning morphology T0

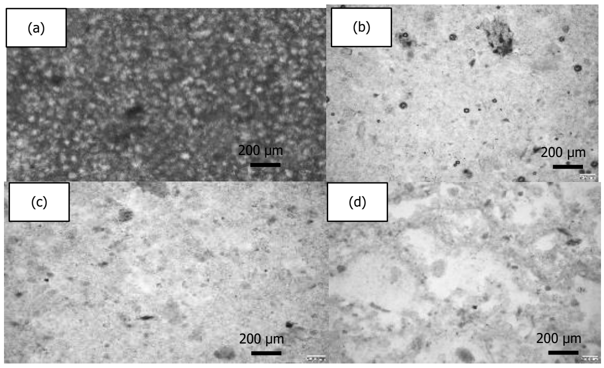


Figure 6. W/O/W double emulsion seasoning morphology T1

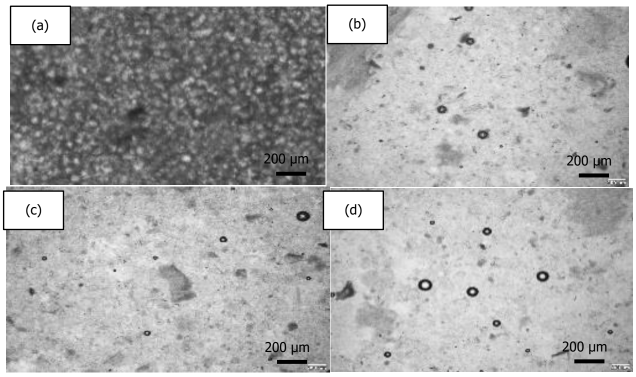


Figure 7. W/O/W double emulsion seasoning morphology T3

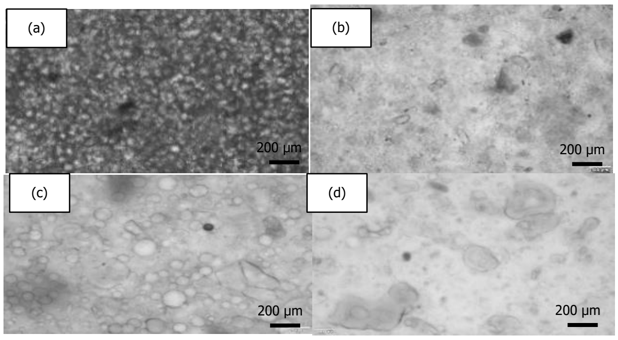


Figure 8. W/O/W double emulsion seasoning morphology T5

Seasoning Particle Fineness

Viewed from particle fineness, overall seasoning emulsion particle is divided into 3 categories: very fine; fine; and sufficiently fine. Seasoning particle fineness can be seen in Table 5. The tendency shown is from very fine to fine and to sufficiently fine along with storage duration. Several treatments, such as low temperature storage (NaCl 0.2% and 0.8%); room temperature storage (NaCl 0%; 0.2% and 0.8%) and high temperature storage (NaCl 0%; 0.2% and 0.8%), show the ability to retain particle fineness well enough throughout storage. Particle fineness change towards a very fine category shows a reduction of droplets' radius, area, and boundary. Fluctuating particle fineness shows the high instability of the emulsion system because droplets continue to experience physical characteristic changes.

The instability that can change droplet size includes coalescence, phase inversion, and disproportionation (Ostwald ripening). This is consistent with McClements' (2016) opinion which stated that disproportionation is a phenomenon in which small droplets experience size reduction and big droplets expand so that there is an overall droplet size increase. The phenomenon occurs because of higher concentration of solubles around small droplets than around big droplets in a polydispersion emulsion system.

W/O/W double emulsion has better particle fineness than seasoning. This can be seen based on particle fineness category which appears on double emulsion, that is, very fine – fine, whereas the category which appears on seasoning is very fine – sufficiently fine.

Table 5. Seasoning particle fineness

Treatment	Storage length (in the week)	Low temperature		Room temperature		High temperature	
		D_{90}	Particle fineness	D_{90}	Particle fineness	D_{90}	Particle fineness
T0	0	244.00	Fine	244.00	Fine	244.00	Fine
	1	4.22	Very fine	226.20	Fine	198.00	Fine
	2	13.54	Fine	28.95	Fine	137.50	Fine
	3	102.70	Fine	128.10	Fine	151.00	Fine
T1	0	10.60	Fine	10.60	Fine	10.60	Fine
	1	13.18	Fine	28.36	Fine	95.47	Fine
	2	13.76	Fine	175.80	Fine	160.20	Fine
	3	136.20	Fine	248.30	Fine	138.10	Fine
T2	0	10.06	Very fine	10.06	Very fine	10.06	Very fine
	1	11.97	Fine	53.08	Fine	97.08	Fine
	2	13.54	Fine	13.48	Fine	287.80	Fine
	3	76.12	Fine	129.40	Fine	154.70	Fine
T3	0	10.40	Very fine	10.40	Very fine	10.40	Very fine
	1	12.98	Fine	221.10	Fine	153.90	Fine
	2	13.84	Fine	28.55	Fine	162.40	Fine
	3	129.80	Fine	133.60	Fine	193.50	Fine
T4	0	11.50	Fine	11.50	Fine	11.50	Fine
	1	27.54	Fine	9.17	Fine	204.10	Fine
	2	11.91	Fine	450.00	Fine	250.20	Fine
	3	155.50	Fine	102.20	Fine	190.70	Fine
T5	0	7.55	Very fine	7.55	Very fine	7.55	Very fine
	1	12.76	Fine	145.50	Fine	246.50	Fine
	2	13.73	Fine	29.19	Fine	261.70	Fine
	3	138.60	Fine	149.40	Fine	206.30	Sufficiently fine

Table 6. Seasoning particle distribution

Particle fineness	Particle fineness	Particle fineness		Particle fineness		Particle fineness	
		D_{90}/D_{10}	Particle distribution	D_{90}/D_{10}	Particle distribution	D_{90}/D_{10}	Particle distribution
T0	0	72.49	Very wide	72.49	Very wide	72.49	Very wide
	1	6.43	Wide	43.02	Very wide	35.96	Very wide
	2	8.64	Good	9.20	Good	39.73	Sufficiently good
	3	30.19	Very wide	26.18	Very wide	24.43	Very wide
T1	0	10.03	Very wide	10.03	Very wide	10.03	Very wide
	1	10.78	Very wide	11.80	Very wide	20.65	Very wide
	2	9.69	Good	35.87	Sufficiently good	33.49	Sufficiently good
	3	30.44	Very wide	34.56	Very wide	21.85	Very wide
T2	0	10.62	Very wide	10.62	Very wide	10.62	Very wide
	1	11.83	Very wide	26.58	Very wide	21.26	Very wide
	2	11.01	Sufficiently good	9.78	Good	61.07	Sufficiently good
	3	16.08	Very wide	26.84	Very wide	25.78	Very wide
T3	0	10.98	Very wide	10.98	Very wide	10.98	Very wide
	1	9.83	Wide	55.07	Very wide	29.74	Very wide
	2	9.17	Good	12.66	Sufficiently good	33.27	Sufficiently good
	3	28.98	Very wide	27.21	Very wide	35.25	Very wide
T4	0	10.21	Very wide	10.21	Very wide	10.21	Very wide
	1	14.28	Very wide	8.21	Wide	42.23	Very wide
	2	8.42	Good	178.08	Sufficiently good	39.85	Sufficiently good
	3	38.46	Very wide	22.59	Very wide	35.32	Very wide
T5	0	8.60	Wide	8.60	Wide	8.60	Wide
	1	10.38	Very wide	31.66	Very wide	38.58	Very wide
	2	10.16	Sufficiently good	9.37	Wide	40.13	Sufficiently good
	3	30.02	Very wide	28.57	Very wide	9.92	Wide

Seasoning particles have a bigger radius, area, and boundary than W.O.W double emulsion particles.

Seasoning Particle Distribution

Seasoning particle distribution in Table 6 shows sufficiently varying categories, namely very wide, wide, good, and sufficiently good. This is different from the double emulsion, the addition of basic seasoning increases seasoning emulsion particle distribution.

NaCl seasoning 0-0.8% shows a very wide category for 0-day storage. based on the data, no best treatment is found in maintaining particle distribution along the storage duration. However, a not too sharp change occurs in low temperature (NaCl 0% and 0.6%) and room temperature (NaCl 0%; 0.4% and 1%) deviation treatments, that is, from very wide, wide, and good. The seasoning particle shows a positive change because of the increase in particle size uniformity during storage. The phenomenon that occurs on seasoning droplets is flocculation, in which two droplets stick to one another without core union. Droplets can escape from one other due to the increase of inter-droplet repulsion force and reduction of inter-droplet attraction force. On the contrary, an emulsion system with wider distribution shows a reduction of inter-droplet repulsion force. Electrostatic force in an emulsion system is influenced by NaCl existence. This is in line with the opinion of Wang *et al*. (2017), which stated that NaCl potentially increases emulsion instability through a reduction of electrostatic force. Higher NaCl concentration causes a reduction of repulsion force so that droplet size increases. Temperature is another factor that also influences the repulsion force. This is supported by McClements' (2016) opinion which stated that heating causes reduction of steric repulsion force due to non-ionic emulsifier polar cluster hydration so that droplets move closer to one another. Emulsion droplet distribution change is influential towards seasoning. Emulsion droplets that have experienced physicochemical characteristics during storage will not operate salty taste release continuously, because the salt has been diffused and is out of the internal water phase towards the external water phase.

CONCLUSION

Storage temperature influences W/O/W double emulsion and seasoning instability phenomenon. Low temperature and high-temperature storage double emulsion morphology show flocculation and coalescence, whereas room temperature storage shows diffusion from the internal water phase to the external water phase. Low temperature and room temperature storage seasoning morphology show diffusion from the internal water phase to external water phase, whereas high-temperature storage morphology shows diffusion from the external water phase to water internal phase. Room temperature is a relatively more effective storage than low temperature and high temperature. The double emulsion has better particle fineness and distribution than seasoning. Various instability phenomena which influence seasoning particle morphology, fineness and distribution show that the rate of salt release during storage is quite high so that the salty taste perception mechanism doesn't work as expected.

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